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(54) **OBTAINING VEHICLE TRAFFIC INFORMATION USING MOBILE BLUETOOTH DETECTORS**

(71) Applicant: **HERE GLOBAL B.V.**, Veldhoven (NL)

(72) Inventor: **Lawrence M. Peterson**, Downers Grove, IL (US)

(73) Assignee: **HERE Global B.V.**, Eindhoven (NL)

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H04W 4/00	(2009.01)
H04W 4/02	(2009.01)

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CPC *G08G 1/0112* (2013.01); *G01S 5/0027* (2013.01); *G08G 1/0116* (2013.01); *H04W 4/008* (2013.01); *H04W 4/027* (2013.01); *H04W 4/028* (2013.01)

(58) **Field of Classification Search**
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Primary Examiner — Hai V Nguyen
(74) *Attorney, Agent, or Firm* — Lempia Summerfield Katz LLC

(57) **ABSTRACT**

A method and system for obtaining traffic information from mobile Bluetooth detectors is disclosed. A mobile Bluetooth detector is a device located in a moving vehicle that includes Bluetooth and GPS firmware for collecting data from Bluetooth enabled devices. The mobile Bluetooth detector transmits the collected data to a remote facility where the data is processed to generate traffic information. A pair of mobile Bluetooth detectors may be used to collect data for generating ground truth.

20 Claims, 4 Drawing Sheets
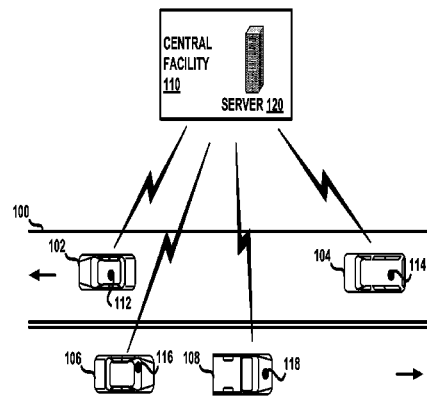
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Fig. 1

200

DATA
STORAGE
<u>204</u>

POSITIONING
SYSTEM
<u>206</u>

PROCESSOR
<u>202</u>

USER
INTERFACE
<u>210</u>

COMMUNICATION
MODULE
<u>208</u>

Fig. 2

300

COLLECT BLUETOOTH
AND GPS DATA — 302

TRANSMIT BLUETOOTH
DATA TO CENTRAL
FACILITY — 304

GENERATE TRAFFIC
INFORMATION FROM
BLUETOOTH DATA — 306
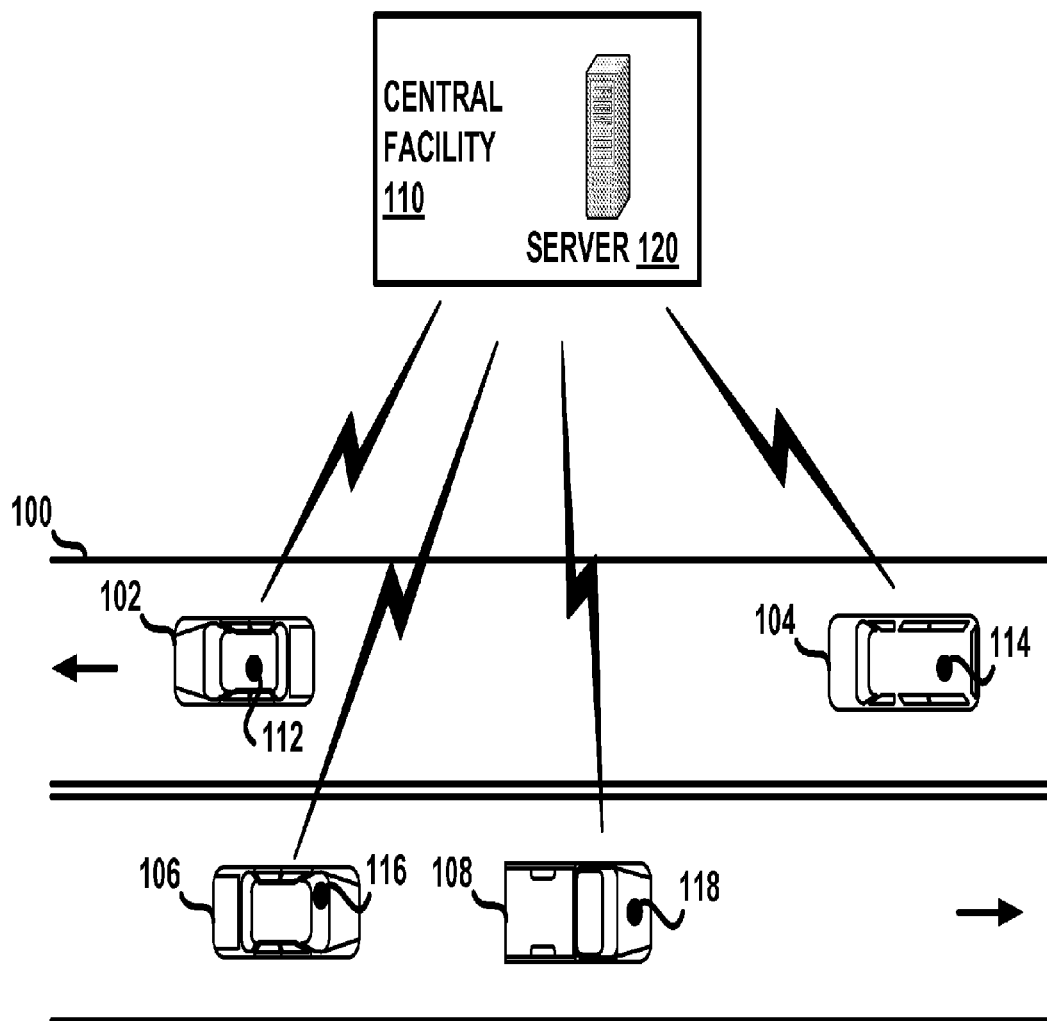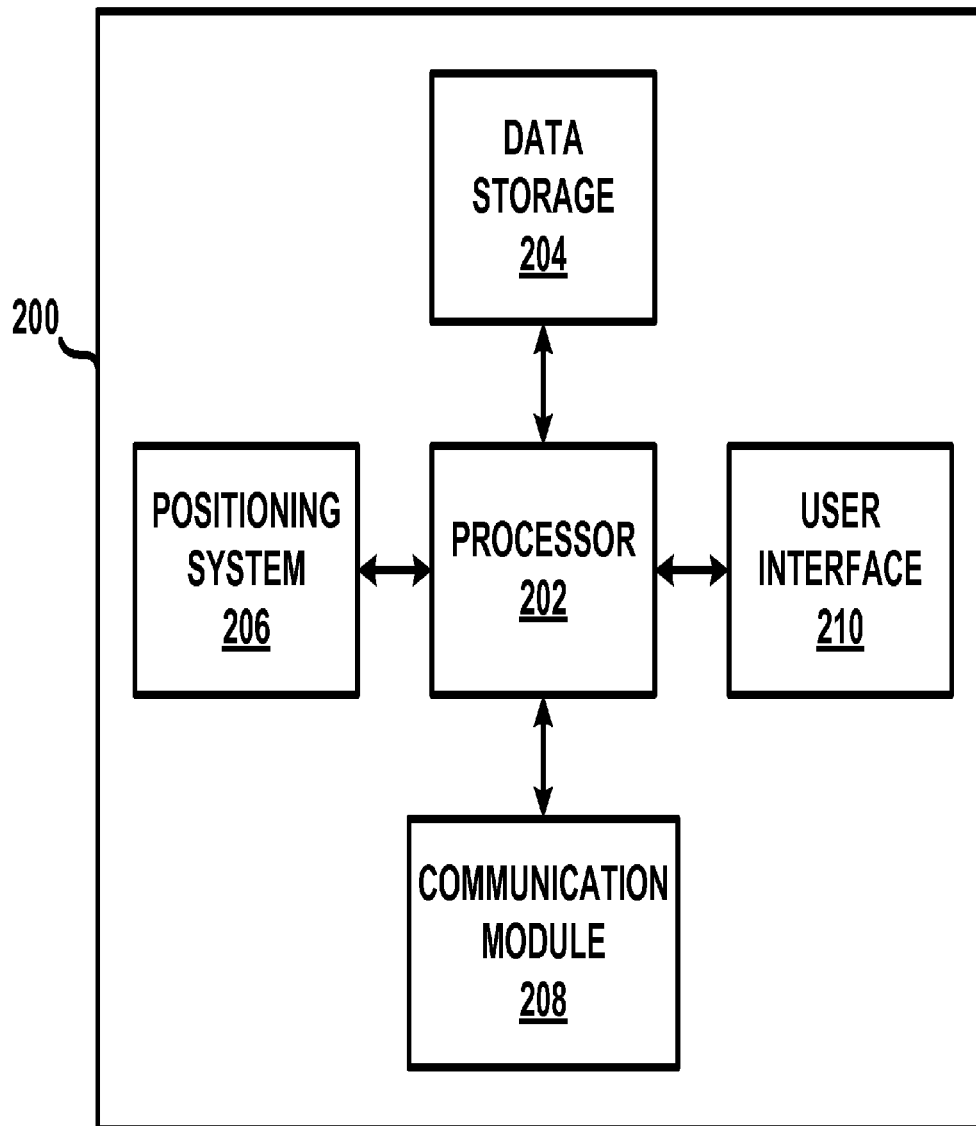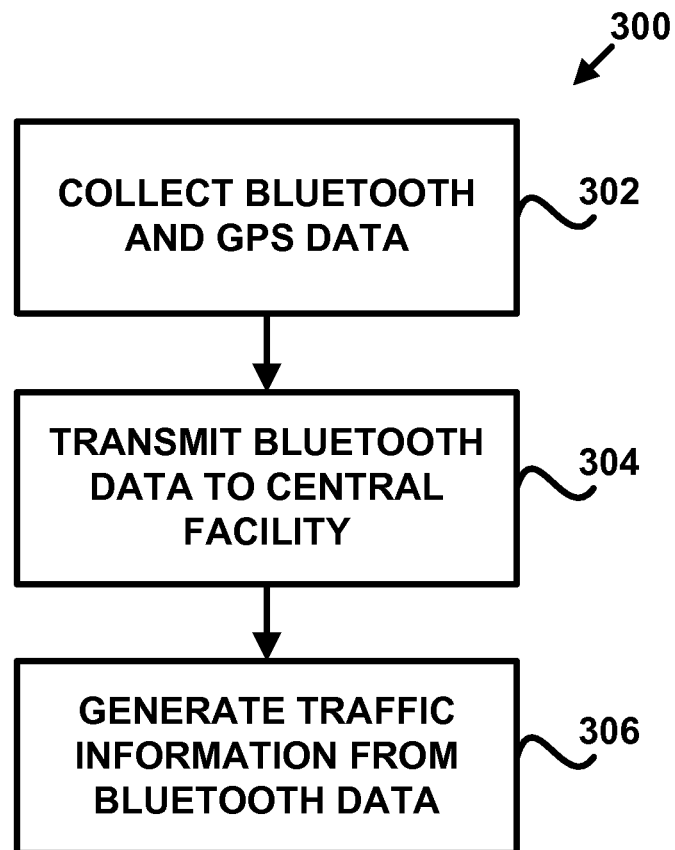
Fig. 3

macaddr1:

BLUETOOTH LOG:	date 1 time 1 macaddrA
	date 1 time 2 macaddrB
GPS LOG:	date 1 time 1 locationW
	date 1 time 2 locationX

402

macaddr2:

BLUETOOTH LOG:	date 1 time 3 macaddrA
	date 1 time 4 macaddrB
GPS LOG:	date 1 time 3 locationY
	date 1 time 4 locationZ

404

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Fig. 4

macaddr1 date 1 time 1 macaddrA locationW
macaddr1 date 1 time 2 macaddrB locationX
macaddr2 date 1 time 3 macaddrA locationY
macaddr2 date 1 time 4 macaddrB locationZ

500

Fig. 5

OBTAINING VEHICLE TRAFFIC INFORMATION USING MOBILE BLUETOOTH DETECTORS

This application is a continuation under 37 C.F.R. §1.53 (b) and 35 U.S.C. §120 of U.S. patent application Ser. No. 13/097,310 filed Apr. 29, 2011, which in incorporated by reference in its entirety.

FIELD

The present invention relates generally to vehicle traffic, and more particularly, relates to using mobile Bluetooth detectors to obtain vehicle traffic information.

BACKGROUND

Bluetooth is an open wireless technology standard for exchanging data over short distances using short length radio waves from fixed and mobile devices, creating personal area networks (PANs) with high levels of security. A Bluetooth detector is a device that can read and record the unique Media Access Control (MAC) address of other Bluetooth devices that come into radio frequency range of the detector and attempt to establish a Bluetooth connection. When equipped with a Global Positioning System (GPS) device, a Bluetooth detector can also record from where and at what time the unique MAC address was received.

Bluetooth detectors have been placed alongside roads to monitor traffic conditions. Two stationary Bluetooth detectors placed apart from each other alongside a road may observe a vehicle containing a detectable Bluetooth device at two different times. Each detector logs the MAC address of the device in the vehicle and the time of detection. This information may be used to calculate a travel time and speed for a detected vehicle to travel on the road between the two detectors.

While the traffic information obtained from these statically located Bluetooth detectors is useful, the information is limited to just the road located between the detectors. Due to the costs involved with installing and maintaining the Bluetooth detector equipment, it is unlikely that Bluetooth detectors will be deployed alongside roadways in a manner sufficient to cover large portions of a road network. Thus, it would be beneficial to obtain traffic information from Bluetooth detectors in another manner.

SUMMARY

A method and system for obtaining traffic information from mobile Bluetooth detectors is disclosed. A mobile Bluetooth detector is located in a moving vehicle. The detector includes a positioning system (e.g., a GPS system) that detects the location (e.g., latitude and longitude) of the vehicle. The detector also includes a processor that executes machine language instructions stored in data storage to collect data regarding Bluetooth enabled devices attempting to connect with the mobile Bluetooth detector. The detector also includes a communication module that transmits the collected data to a remote facility that generates traffic information.

The method for obtaining traffic information from mobile Bluetooth detectors includes providing a first device in a first vehicle moving in a geographic area. The first device has Bluetooth and GPS capabilities. The method further includes collecting data regarding other devices attempting to connect with the first device. The other devices are located

near the first device (i.e., within Bluetooth transmission range). The collected data includes when and where the other devices attempted to connect with the first device. The method also includes transmitting the collected data to a remote facility to generate traffic information.

The remote facility merges the data received from Bluetooth detectors by timestamp and MAC address, and uses map matching to generate traffic information from the merged data. The traffic information may include traffic speeds and travel times of the detected devices. When a pair of mobile Bluetooth detectors is used to collect data from Bluetooth enabled devices traveling on the same road in a direction opposite from the detector pair, the traffic information may be used as ground truth for testing the accuracy of traffic systems.

These as well as other aspects and advantages will become apparent to those of ordinary skill in the art by reading the following detailed description, with reference where appropriate to the accompanying drawings. Further, it is understood that this summary is merely an example and is not intended to limit the scope of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

Presently preferred embodiments are described below in conjunction with the appended drawing figures, wherein like reference numerals refer to like elements in the various figures, and wherein:

FIG. 1 depicts a portion of a road, according to an example;

FIG. 2 is a simplified block diagram of a Bluetooth detector, according to an example;

FIG. 3 is a flow chart of a method for obtaining traffic information using mobile Bluetooth detectors, according to an example;

FIG. 4 depicts logs from two Bluetooth detectors, according to an example; and

FIG. 5 depicts processed Bluetooth detector log data from the logs depicted in FIG. 4, according to an example.

DETAILED DESCRIPTION

FIG. 1 depicts a road 100 that is part of a road network in a geographic area. Four vehicles 102-108 are depicted as traveling on the road 100. Two vehicles 102, 104 are traveling in one direction as denoted by an arrow, and the other two vehicles 106, 108 are traveling in the opposite direction also denoted by an arrow.

Each of the vehicles 102-108 may include a device 112-118 with Bluetooth capability. Bluetooth devices include some mobile telephones, navigation systems, headsets, watches, cameras, PDAs, music players, and so on. The devices 112-118 may also include GPS capability. The devices 112-118 that include both Bluetooth and GPS capability may be used as a mobile Bluetooth detector. For example, many types of mobile telephones may be used as a mobile Bluetooth detector.

While the vehicles 102-108 are shown as cars, trucks, and buses, the vehicles 102-108 may also be motorcycles, bicycles, carts, and any other structures used for transporting people or goods. Vehicles, such as trains and boats, not associated with the road 100 may also be used to transport Bluetooth detectors. Additionally, pedestrians may transport Bluetooth detectors. Thus, the term "vehicle" as used herein is intended to cover any thing or person that can move a Bluetooth detector in a geographic area.

Moreover, it is understood that the vehicles may temporarily stop (e.g., at a stop sign, traffic light, railroad crossing) and still be considered to be a moving vehicle. Thus, the term "mobile" as used herein means that the vehicle is not fixed in a permanent or long term position.

FIG. 2 is a simplified block diagram of a mobile Bluetooth detector 200 that may be included as part of the devices 112-118. The Bluetooth detector 200 may be a combination of hardware, software, and firmware components. The Bluetooth detector 200 includes a processor 202 and a data storage device 204. The processor 202 may be a general purpose processor or a special purpose processor (e.g., digital signal processor). The data storage device 204 may be one or more memory modules that contain software programs, data stores, and other electronic information. For example, the processor 202 may execute computer-readable program instructions contained in the data storage device 204.

The data storage device 204 may also contain firmware (and/or software) providing Bluetooth and GPS capabilities. Bluetooth and GPS capabilities are already built into many cellular phones as part of the cell phone's operating system or application suite. The same is true for many personal navigation devices used by consumers for routing and navigation. The Bluetooth firmware records the MAC addresses and time of reception or detection for each MAC address of all other Bluetooth enabled devices attempting a connection, and saves this information in a log. The GPS firmware records the GPS location and time, and saves this data in a log. Both logs are also stored in the data storage device 204.

The Bluetooth detector 200 also includes a positioning system 206 that determines location. The positioning system 206 may utilize GPS-type technology. The positioning system 206 may also include sensing devices that measure traveling distance, speed, direction, orientation, and so on. The positioning system 206 outputs a signal to the processor 202.

The Bluetooth detector 200 also includes a communication module 208. The communication module 208 is operable to transmit data to and receive data from a remote device. For example the data may be voice, text, or multimedia data. The remote device may be another mobile Bluetooth detector, a computer, or another type of device.

The Bluetooth detector 200 may also include a user interface 210. The user interface 210 may include a keypad having one or more keys (e.g., switches) that are operable to input data into the detector 200. As another example, the user interface 210 may include a microphone and associated electronic circuitry that are operable to input data into the Bluetooth detector 200. The user interface 210 also allows an end user to obtain information from the Bluetooth detector 200.

As the mobile Bluetooth detector 200 moves along the road 100 in one of the vehicles 102-108, the Bluetooth detector 200 may detect other Bluetooth enabled devices. To detect other Bluetooth enabled devices, the devices are within the Bluetooth transmission range of the Bluetooth detector 200. While class 1 Bluetooth devices currently have a transmission range up to 100 meters, it is expected that the range will increase over time. The Bluetooth enabled devices may be moving or stationary.

When the Bluetooth detector 200 detects a Bluetooth enabled device, the Bluetooth detector 200 logs the MAC address of the other device and data associated with when the Bluetooth detector 200 detected the other device. The Bluetooth detector 200 also logs data associated with where

the Bluetooth detector 200 detected the other device. The Bluetooth detector 200 may also log other data regarding the detected device, such as device attributes, which provide generic information regarding the detected device. The device attributes may be used in filtering data, identifying vehicles, and/or classifying the detected device.

The communication module 208 transmits the Bluetooth log, the GPS log, and the MAC address of the Bluetooth detector 200 to a central facility 110 for processing. The communication module 208 may also transmit other data, such as the device attributes, to the central facility 110. The MAC address of the Bluetooth detector 200 identifies the unique source of the data. Alternatively, the communication module 208 may transmit a unique identifier other than the MAC address. This unique identifier may be anonymous for security purposes.

The central facility 110 includes a server 120. The server 120 is a computing platform that includes a combination of hardware, software, and/or firmware. For example, the server 120 may include a processor, memory, and a communication system. The communication system receives the GPS and Bluetooth logs, MAC address, and possibly other data from the Bluetooth detector 200 and stores the received data in the memory.

The processor in the server 120 then analyzes the data in the logs to generate traffic information. The traffic information may include traffic speeds and travel times. The traffic information may also include ground truth. Ground truth is used to verify the quality and accuracy of traffic data. Ground truth data is typically collected by trained drivers in test vehicles equipped with accurate GPS devices that collect the average speeds of the vehicles on the road at the same location as the test vehicle. However, test vehicles are expensive, collect limited test data, and are less suitable for testing roadways that have traffic controls due to the number of test vehicles needed to accurately measure average conditions in a variable environment.

FIG. 3 is a flow chart of a method 300 for obtaining traffic information using mobile Bluetooth detectors. At block 302, mobile Bluetooth detectors collect Bluetooth and GPS data. For example, the devices 112, 114 within the vehicles 102, 104 may be mobile Bluetooth detectors. In this example, the devices 112, 114 may detect the Bluetooth enabled devices 116, 118 as the vehicles 102, 104 pass the vehicles 106, 108 traveling on the opposite side of the road 100.

The mobile Bluetooth detectors 112, 114 log the collected data. The Bluetooth detectors 112, 114 include hardware, software, and/or firmware to record the MAC addresses and time of reception for each of the MAC addresses in a Bluetooth log. In addition, the detectors 112, 114 include hardware, software, and/or firmware to record the GPS location and time in a GPS log.

FIG. 4 depicts example logs 402, 404. While FIG. 4 depicts two logs, it is understood that many detectors may generate many logs. The logs 402, 404 include a Bluetooth log and a GPS log. The log 402 may be a log generated by the Bluetooth detector 112 and the log 404 may be a log generated by the Bluetooth detector 114. In this example, macaddr1 is the MAC address for Bluetooth detector 112 and macaddr2 is the MAC address for Bluetooth detector 114.

The Bluetooth detector 112 detected the MAC address for device A at date 1 and time 1 when the Bluetooth detector 112 was located at location W. The Bluetooth detector 112 detected the MAC address for device B at date 1 and time 2 when the Bluetooth detector 112 was located at location X. The Bluetooth detector 114 detected the MAC address for

device A at date 1 and time 3 when the Bluetooth detector **114** was located at location Y. The Bluetooth detector **114** detected the MAC address for device B at date 1 and time 4 when the Bluetooth detector **114** was located at location Z.

Returning to FIG. **3**, at block **304**, the mobile Bluetooth detectors transmit the collected data to a central facility. For example, the Bluetooth detector **112** may transmit the log **402** along with the detector's MAC address (i.e., macaddr1) to the central facility **110** and the Bluetooth detector **114** may transmit the log **404** along with the detector's MAC address (i.e., macaddr2) to the central facility **110**. The mobile Bluetooth detectors **112**, **114** may transmit the data at regular time or travel distance intervals. Alternatively, the mobile Bluetooth detectors **112**, **114** may transmit the data continuously or based on a schedule, a triggering event, or at any other time.

At block **306**, the server **120** at the central facility **110** generates traffic information from the received data. After receiving the data, the server **120** merges the data from the logs **402**, **404** by timestamp and MAC address, and stores the merged data into a database. For example, FIG. **5** depicts merged data **500** from the logs **402**, **404**.

With the merged data **500**, the server **120** determines that the Bluetooth enabled device associated with macaddrA traveled from location W to location Y between times 1 and 3 on date 1. Similarly, the server **120** determines that the Bluetooth enabled device associated with macaddrB traveled from location X to location Z between times 2 and 4 on the same day.

The server **120** performs map matching of the merged data **500** to generate traffic speeds and travel times. Map matching compares outputs from a positioning system (e.g., a GPS system) with digital map data in a geographic database to determine the most likely location of the positioning system on the digital map. The server **120** may include a geographic database stored in memory to perform the map matching. Alternatively, the server **120** may use the communication system to access a geographic database located remote from the server **120**. The geographic database may be a geographic database published by NAVTEQ North America, LLC of Chicago, Ill.

The server **120** may filter the merged data **500** prior to analyzing the data to generate traffic information. For example, not all Bluetooth enabled devices are located in a vehicle traveling on a road network. During map matching, the server **120** may determine whether the Bluetooth detector **200** is in a vehicle moving on the road network. Bluetooth signals from pedestrians, households, and other non-vehicular Bluetooth devices may be removed from the merged data **500**. Bluetooth signals from vehicles not traveling on a roadway, such as trains and boats, may also be removed from the merged data **500**. The additional device attributes logged at the time of detection may assist in classifying the detected devices as being located in a vehicle.

To remove Bluetooth signals from the merged data **500**, the server **120** may compare detections from macaddrA and macaddrB with reference to the locations and times for macaddr1 and macaddr2 to determine if macaddrA and macaddrB "act" like vehicles moving along a roadway. In other words, the server **120** processes the data collected by macaddr1 and macaddr2 into logical vehicle speeds along a roadway path. In order to do this, the server **120** determines the speed and direction of macaddrA and macaddrB over time. The server **120** determines if the speeds are logical vehicle speeds and direction of travel indicate a general roadway path. If the locations for macaddr1 and macaddr2 are on a roadway traveling in the same direction, the data for

macaddrA and macaddrB may show travel times and speeds in the opposite direction from macaddr1 and macaddr2.

If macaddrA and macaddrB are stopped or moving slowly, the server **120** looks for higher speeds at a previous time along the roadway. If recent faster speeds along the roadway are known, then the slower speeds can be retained. If no high speed data is seen from macaddrA or macaddrB, then the data from these devices may be removed from the merged data **500** because this data may not be vehicular data.

To distinguish stopped vehicles from pedestrians, the server **120** may develop a profile of speeds and map matched roadway locations for each MAC address detected by a series of Bluetooth detectors. The profiles of detected Bluetooth devices create a picture of what is happening on the roadway. For example, if one detected Bluetooth device is stopped (e.g., a pedestrian or a disabled vehicle) and the other detected devices around the stopped device indicate movement on the roadway, then the data from stopped device may be removed from the merged data **500**.

As previously mentioned, the mobile Bluetooth detector **200** may also be used to create a ground truth for testing roadways. For ground truth, a pair of Bluetooth detectors **200** separated by a variable distance and traveling in the same direction on the same roadway is used to determine the speeds or travel times of vehicles containing Bluetooth enabled devices traveling in the opposite direction on the same roadway. Preferably, the distance between the Bluetooth detectors is between one and five miles; however, other distances may be used. The mobile Bluetooth collection pairs (e.g., detectors **112**, **114**) can log and measure many ground truth samples from the Bluetooth enabled devices in vehicles traveling in the opposite direction on the same roadway (e.g., devices **116**, **118**).

The remote facility **110** may provide the traffic information to businesses providing a traffic service (i.e., B2B) and/or consumers using various traffic enabled devices, such as a navigation system (i.e., B2C). For example, a traffic data supplier may provide the traffic information in the form of one or more data feeds, such as an RSS or XML feed.

Mobile Bluetooth detectors overcome the problems with static Bluetooth detectors and test vehicles. The mobile Bluetooth detectors provide large volumes of floating car data (FCD), which allows traffic data suppliers to generate traffic information with reduced cost and expanded coverage. Moreover, the traffic data suppliers may use pairs of mobile Bluetooth detectors to accurately test vehicle speeds on all types of roads at a reduced cost.

It is intended that the foregoing detailed description be regarded as illustrative rather than limiting and that it is understood that the following claims including all equivalents are intended to define the scope of the invention. The claims should not be read as limited to the described order or elements unless stated to that effect. Therefore, all embodiments that come within the scope and spirit of the following claims and equivalents thereto are claimed as the invention.

I claim:

1. A method comprising:

receiving, by a plurality of mobile detecting devices, location data for a plurality of wireless devices;

receiving, by the plurality of mobile detecting devices, identification data indicative of device identifiers of the plurality of wireless devices;

storing received location data of the plurality of wireless devices in a location log of each mobile detecting device that has received location data;

storing received identification data indicative of device identifiers in a connection log of each mobile detecting device that has received identification data;

merging location logs of the plurality of mobile detecting devices and the connection logs of the plurality of mobile detecting devices into a traffic database; and

generating traffic data based on location data and connection data of wireless devices from the merged location logs and merged connection logs of the traffic database.

2. The method of claim 1, further comprising:

providing travel times or traffic speeds based on the traffic data.

3. The method of claim 1, further comprising:

comparing the location data to map data from a geographic database; and

matching the location data to locations in the map data.

4. The method of claim 3, further comprising:

filtering at least one of the plurality of wireless devices when the location data is not on a roadway.

5. The method of claim 4, wherein the filtered at least one of the plurality of wireless devices corresponds to a boat or a train.

6. The method of claim 1, further comprising:

comparing the location data for each of the plurality of wireless devices to a range of speeds; and

filtering the location data outside of the range of speeds.

7. The method of claim 6, wherein the filtered location data corresponds to a pedestrian, or a disabled vehicle.

8. The method of claim 1, wherein the location log distinguishes between the plurality of wireless devices using media access control (MAC) addresses.

9. An apparatus comprising:

at least one processor; and

at least one memory including computer program code for one or more programs; the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to at least perform:

receive, a plurality of location logs from a plurality of mobile detecting devices, wherein the location logs each include location data for a plurality of wireless devices;

receive, a plurality of connection logs from the plurality of mobile detecting devices, each connection log including identification data indicative of connection attempts for the plurality of wireless devices;

aggregate, by the at least one processor, the plurality of location logs and the plurality of connection logs into a traffic database; and

generate traffic data based on the aggregated plurality of location logs and the plurality of connection logs of the traffic database.

10. The apparatus of claim 9, further comprising:

provide travel times or traffic speeds based on the traffic data.

11. The apparatus of claim 9, further comprising:

compare the location data to map data from a geographic database; and

match the location data to a location in the map data.

12. The apparatus of claim 11, further comprising:

filter at least one of the plurality of wireless devices when the location data is not on a roadway.

13. The apparatus of claim 12, wherein the filtered at least one of the plurality of wireless devices corresponds to a boat or a train.

14. The apparatus of claim 12, further comprising:

compare the location data for each of the plurality of wireless devices to a range of speeds; and

filter the location data outside of the range of speeds.

15. The apparatus of claim 14, wherein the filtered location data corresponds to a pedestrian, or a disabled vehicle.

16. The apparatus of claim 9, wherein the location log distinguishes between the plurality of wireless devices using media access control (MAC) addresses.

17. A non-transitory computer readable medium configured to store instructions, executable by a processor, to perform:

receiving by a plurality of mobile detecting devices location data for a plurality of wireless devices;

receiving, by the plurality of mobile detecting devices, identification data indicative of device identifiers of the plurality of wireless devices;

receiving location data for each of the plurality of mobile detecting devices associated with a time of each received location data for the plurality of wireless devices;

merging location data for the plurality of wireless devices, identification data received from the plurality of mobile detecting devices, and location data for the plurality of mobile detecting devices;

comparing the location data for the plurality of wireless devices to a predetermined map;

comparing the location data for the plurality of wireless devices to a speed profile;

filtering the location data for the plurality of wireless devices according to the speed profile or the predetermined map; and

generating traffic data based on the location data for the plurality of wireless devices, the location for the plurality of mobile detecting devices, and the identification data indicative of device identifiers of the plurality of wireless devices.

18. The non-transitory computer readable medium of claim 17, the instructions further configured to perform:

storing received location data of the plurality of wireless devices in a location log of each mobile detecting device that has received location data; and

storing received identification data indicative of device identifiers in a connection log of each mobile detecting device that has received identification data.

19. The non-transitory computer readable medium of claim 17, wherein the filtered location data for the plurality of wireless devices corresponds to locations outside of a roadway.

20. The non-transitory computer readable medium of claim 17, wherein the filtered location data for the plurality of wireless devices corresponds to a pedestrian, a train, a boat, or a disabled vehicle.

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